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providing we add the further conditions that the standard deviations in all of the primary causes are equal and that the effects of all of the primary causes are equal. These conditions appear at first very limited, and in a practical case it is necessary at least qualitatively to check the assumptions underlying equation (4), but in general it has been found that a significant deviation in r may be taken to indicate a variation in the effects of one or more groups of primary causes, upon one of the variables and not upon the other.

A more complete account of this investigation giving experimental data, will be published elsewhere.

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[1] Pearson, K. "Tables for Statisticians and Biometricians" pp. (26–28) and *Phil. Mag.*, Ser. 5, **1**, 1900.

[2] Edgeworth, F. Y., *Camb. Phil. Trans.*, **20**, 1904 (36–65) and (113–141).

ELECTRONIC BOMBARDMENT OF NICKEL

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Studies of the secondary (emergent) electrons produced by electronic bombardment of metal surfaces have previously been made by various experimenters.[1] However, the fact that most of the results were obtained previous to the development of modern high vacuum technique combined with the failure of the small amount of recent work to agree with these older results, leaves the important questions of this problem still unanswered. It is well known that the number of secondary electrons depends upon the velocity of the primary (incident) beam, that more electrons leave the surface than strike it if the primary velocity is great enough, but the following characteristics of the various metals are still not definitely determined: (1) the magnitude of the secondary electron current as a function of the primary velocity; (2) the velocity distribution of the secondary electrons for any given primary velocity.

The present investigation is an attempt to obtain these characteristics for nickel. The type of apparatus employed was such that a primary electron stream, of uniform velocity and cross-section, could be made either to impinge on a nickel target or to pass into an absorbing Faraday cylinder. This was accomplished by moving the target, by means of a magnetic control, over a hole in the Faraday cylinder into the path of the primary stream. The secondary electrons which left the target were received by a conducting cylinder. This arrangement made it possible to move the target out to the side of the tube where it could be heated to bright red heat by high-frequency induction currents.

The ratio of the secondary to the primary electron current was studied, especially as affected by: (1) prolonged heating of the bombarded surface at bright red heat; (2) condition of the surface; (3) nature of the gas to which it had been exposed. This ratio, for low primary velocities (less than 260 volts), decreased with prolonged heating, and the general shape of the secondary electron curve was changed. A limiting form of this curve was obtained, see figure 1, which was independent of whether the apparatus had previously been exposed to air or hydrogen; so it seems safe to conclude that the final curve is one which represents the true characteristics of nickel. The number of secondary electrons was found to be independent of the roughness of the surface, but covering the surface with fine nickel gauze considerably reduced this secondary electron current. Secondary electrons were found when the primary velocity was as low as 0.2 volt. In the limiting curve, see figure 1, the ratio of the secondary to the primary current increased rapidly with increase of the primary velocity to a value of 0.15 at about 4 volts, then remained constant to about 9 volts, where it again increased, reaching a value of unity for a velocity of impact corresponding to 260 volts.

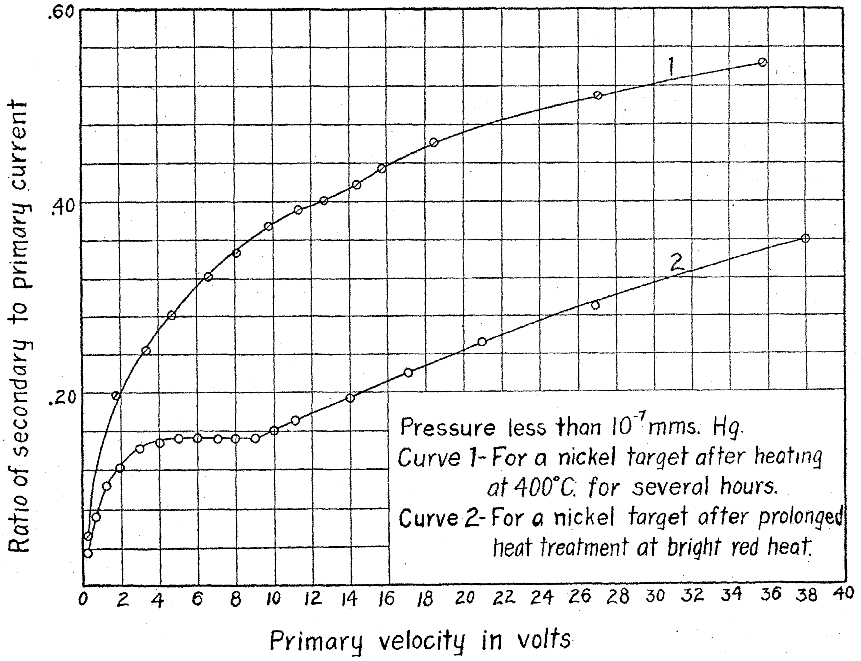

FIG. 1

Measurements of the velocity distribution of the secondary electrons indicate that, below about 9 volts primary velocity, a large percentage of the secondary electrons have velocities nearly equal to the primary velocity and a very small percentage have velocities less than one volt. For higher primary velocities the distribution changes, there being many secondary electrons having low velocities. The percentage of secondary electrons having velocities less than 5 volts, say, increases as the primary velocity increases. There are, however, a few per cent having velocities nearly equal to that of the primary electrons, when the primary velocity is as great as 110 volts.

The following features of the investigation show that a new factor enters into the production of secondary electrons from nickel at about 9 volts: (1) the sudden change in slope of the secondary electron curve at about 9 volts; (2) the difference between the velocity distribution of secondary electrons when the primary velocity is 9 volts or less, and that when the primary velocity is greater than 9 volts. These results lead one to the interpretation that reflection of electrons from nickel occurs for all the primary velocities investigated, the reflection increasing between 0 and 4 volts primary velocity and then remaining constant to 9 volts, where emission begins and increases with increase of primary velocity to at least 260 volts. That there are some high velocity electrons present, when the primary velocity is as great as 110 volts, indicates that reflection continues after emission begins, so that above 9 volts there is both reflection and emission. According to this idea the reflected electrons may be considered to have velocities nearly equal to the primary velocity, i.e., reflection involves a change in direction without much loss in energy, while the emitted electrons have a much smaller velocity.

The above interpretation is further substantiated by a phenomenon which was observed when obtaining the velocity distribution of the primary electrons. It was found that when the primary velocity was less than 9 volts, all of the primary electrons had velocities nearly equal to that corresponding to the applied voltage. For larger primary velocities, however, there were some low velocity electrons present, the number increasing with the primary velocity. This can be explained, in accordance with the previous interpretation, as being due to emission of electrons from the edges of the diaphragms which limit the primary beam. Thus, since below 9 volts no emission occurs there are no low velocity electrons present in the primary beam.

Since the number of secondary electrons obtained at the low velocities was much greater before the continued heating than after, one must conclude that the reflection and emission of electrons from the atoms of gas on a metal surface is greater than from the metal freed from gas.

The method used is particularly well adapted to the extension of the investigation to other metals. Targets of the various metals can be inserted and the characteristics of each studied under the same conditions by moving them successively into the path of the primary electron stream. There is no reason to believe that the secondary electron characteristics should be the same for all metals, and a knowledge of their characteristics in this respect should be of value in connection with the electron theory of metals.

A more detailed account of this work will be published in the *Physical Review* in the near future.

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THE CRYSTAL STRUCTURE OF POTASSIUM

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Potassium, when examined by X-rays at room temperature appears to be amorphous, as previously reported by Hull.[1] But if potassium, cast in a thin-walled cylindrical glass tube, is cooled to —150° C. in a current of air by the method recently employed in getting the crystal structure of mercury,[2] large crystals, giving well marked reflections of the K-radiation of molybdenum, are formed. These crystals are, in fact, so large that it is a matter of some difficulty to obtain enough different orientations in a single sample, and the data are not of great accuracy. Continuous rotation of the sample about the axis of the cylinder so weakens the intensity of the occasional reflections that they can no longer be located with certainty. The best results are obtained by rotating the sample through small angles at such long time-intervals that individual crystals in suitable orientations have long enough to affect the film.

The best fit with the data is furnished by assuming the atoms to be arranged in a body-centered cubic lattice with $a = 5.20 \times 10^{-8}$ cm. and therefore with a density 0.92 gm./cm.[3] This density is higher than